OPTIMIZATION OF SURFACE ROUGHNESS IN MILLING BY USING RESPONSE SURFACE METHOD (RSM)

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A report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor of Mechanical with Manufacturing Engineering

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering With Manufacturing Engineering.

Signature
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Position: Lecturer
Date: 6 December 2010

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature ....
Name: MOHD AIZUDDIN BIN MAT ALWI
ID Number: ME 07017
Date:

To my beloved person

MAT ALWI BIN MUSA

MAIMON BINTI MOHAMMAD

MY SIBLINGS

ALL MY FRIENDS

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ABSTRACT

Aluminium Alloys are attractive materials due to their unique high strength-weight ratio that is maintained at elevated temperatures and their exceptional corrosion resistance. Face mill is used as cutting tool for experiment in milling machine.So in this study, the optimum of surface roughness is optimize by using response surface method. The experiments were carried out using CNC milling machine. The experiment was run with 15 experiment test. All the data was analyzed by using Response Surface Method (RSM) and Neural Network (NN). The result have shown that the feed gave the more affect on the both prediction value of Ra compare to the cutting speed and depth of cut r as P-values is less than 0.05. From the prediction data that shown, the different between both software is smaller and the value is acceptable to get the optimum value of surface roughness.

ABSTRAK

Paduan aluminium merupakan bahan menarik kerana unik nisbah kekuatan-bobot tinggi yang dijaga dalam suhu yang jauh tinggi dan ketahanan kakisan yang luar biasa mereka. Face mill digunakan sebagai alat pemotong untuk percubaan di penggilingan mesin. Jadi dalam kajian ini, optimum kekasaran permukaan dioptimumkan dengan menggunakan kaedah respon permukaan. Percubaan dilakukan dengan menggunakan mesin milling CNC. Percubaan ini berjalan dengan 15 uji eksperimen. Semua data dianalisis dengan menggunakan Kaedah Response Surface (RSM) dan Neural Network (NN). Keputusan kajian menunjukkan bahawa pakan memberikan pengaruh lebih besar atas nilai ramalan kedua Ra dibandingkan dengan kelajuan potong dan kedalaman potong r P-nilai kurang dari 0.05. Dari data ramalan yang dipaparkan, perbezaan antara kedua-dua software tersebut lebih kecil dan nilai yang boleh diterima untuk mendapatkan nilai optimum kekasaran permukaan.

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LIST OF SYMBOLS

mm	-	Millimeter
MPa	-	Megapascal
GPa	-	Gigapascal
%	-	Percent
HB	-	Hardness
kN	-	Kilonewton
lbf	-	Pound of force
σ	-	Stress
P	-	Load
A_o	-	Cross sectional area
A_f	-	Final cross sectional area
e	-	Strain
l	-	Instantaneous length
l_o	-	Original length
dB	-	Decibel
UTS	-	Ultimate tensile strength
Ra	-	Surface Roughness

LIST OF ABBREVIATIONS

UMP	-	Universiti Malaysia Pahang
FKM	-	Fakulti Kejuruteraan Mekanikal
ASTM	-	American Society for Testing and Material
AISI	-	American Iron and Steel Institute
ISO	-	International Organization for Standardization
PZT	-	Piezoelectric Transducer
AE	-	Acoustic Emission
AED	-	Acoustic Emission Detector
AST	-	Auto Sensor Test

CHAPTER 1

1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

Milling is a vital option. Milling is the process of cutting away material by feeding a workpiece past a rotating multiple tooth cutter. The cutting action of the many teeth around the milling cutter provides a fast method of machining. The machined surface may be flat, angular, or curved. The surface may also be milled to any combination of shapes. The machine for holding the workpiece, rotating the cutter, and feeding it is known as the Milling machine.

Recent developments in manufacturing industry have contributed to the importance of CNC milling. Surface roughness is expressed as the irregularities of material resulted from various machining operations. In quantifying surface roughness, average surface roughness definition, which is often represented with *R*a symbol, is commonly used. Theoretically, *R*a is the arithmetic average value of departure of the profile from the mean line throughout the sampling length. *R*a is also an important factor in controlling machining performance. Surface roughness is influenced by cutting speed, feed, depth of cut. Response surface method (RSM) and neural network (NN) was used to make an analysis to get the optimum data.

1.2 PROBLEM STATEMENT

This study involve an optimization of surface roughness in milling using response surface method (RSM). Optimum surface roughness is very important factor in milling or manufacturing industry or field. For example, the quality of plastic products manufactured by plastic injection molding process is highly influenced smoothness of mold surfaces obtained from the milling process. Surface quality of these products is generally associated with surface roughness and can be determined by measuring surface roughness. Optimum surface roughness is analyze by using Response Surface Method (RSM) and alternative method Neural Network (NN).

1.3 PROJECT OBJECTIVE

i. To determine optimum surface roughness in milling process to maximize the production rate, quality of product and minimum production cost in industry.
ii. To predict the surface roughness in milling process to make an optimization.

1.4 PROJECT SCOPE

i. The research will use Response Surface Method (RSM) to optimize milling surface roughness.
ii. Using Neural Network software as artificial intelligent solver.
iii. To get an optimum surface roughness in milling process for industry and daily use to minimize cost, maximize production rate, high quality and low waste material.
iv. Parameter: axial depth : 0.5~2.0mm
Feedrate : 0.1 ~ 0.02mm/ tooth
Cutting speed : 100~ 250mm/ rev

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

From the early stage of the project, various literature studies have been done. Research journal, books, printed or online conference article were the main source in the projects guides. The reference sources emphasize on important aspect of surface roughness and aspect that relate to get it such as machine that used, cutting tool, machining parameter and artificial intelligent.

2.2 MILLING MACHINE

A milling machine is a machine tool used to machine solid materials. Milling machines exist in two basic forms horizontal and vertical, which terms refer to the orientation of the cutting tool spindle. Unlike a drill press, in which the work piece is held stationary and the drill is moved vertically to penetrate the material, milling also involves movement of the work piece against the rotating cutter, the latter of which is able to cut on its flanks as well as its tip. Work piece and cutter movement are precisely controlled to less than 0.001 in (0.025 mm), usually by means of precision ground slides and lead screws or analogous technology. Milling machines may be manually operated, mechanically automated, or digitally automated via computer numerical control (CNC). Milling machines can perform a vast number of operations, some very complex, such as slot and keyway cutting, planning, drilling, die sinking, rebating, routing, etc. Cutting fluid is often pumped to the cutting site to cool and lubricate the cut, and to sluice away the resulting swarf.

2.2.1 CNC MILLING

CNC (Computer Numerical Control) milling machine is one of the common machine tools in machinery industry. It is the popular form of CNC that can perform those repetitive tasks of drilling and turning that used to be human jobs long time ago. CNC Mills are classified based on the number of axes that they have. Axes are labeled as x and y for horizontal movement, and z for vertical movement. Basically, this machine have four axes which are Milling Head Z, Table Z, Table Y, Table X. The quantity of axes it has is often presented in many different ways. For example, there are a five-axis machine. The extra 5th axis is in the form of a horizontal pivot for the milling head that ensure the excellent flexibility of machining with the end mill at an angle follow the table.

It is usually programmed by using a series of standard commands that we named it as G-codes to represent specific CNC tasks in alpha-numeric form. There are many different sizes for this machine based on the purpose and location of usage, as well as the materials that need to be cut. Besides that, the size of motor affects the speed of cutting the materials. Normally, materials like plastic and wood are the easiest things to cut, unlike steel that need more stronger milling machine and longer time. To evaluate the perfomance of milling, we can look at its rigidity. For example, the more rigid a mill is, the more precisely it drills and cuts. CNC mills normally have better & tougher engines for higher rigidity compared to manual counterparts. [Tan.Y.E, 1999]

Figure 2.4a: Haas CNC milling machine

Figure 2.4b: Haas CNC milling machine

2.2.1.1 Face Milling Cutter

The terminology for a face- milling cutter, as well as the various angles. The lead angle of the insert in face milling has a direct influence on underformed chip thickness, as it does in turning operations. In face milling, the cutter is mounted on a spindle having an axis of rotation perpendicular to the workpieces surface and removes material in the manner. The cutter rotates at a rotational speed v. The cutting teeth, such as carbide inserts, are mounted on the cutter body. Because of the relative motion between the cutter teeth and the work piece, face milling leaves feed marks on the machined surface, similar to those left by turning operations. [Harold V.J, 1984]

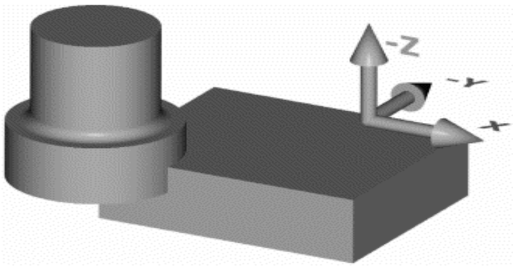

Figure 2.0a: Face Milling Cutting Illustration

Figure 2.0b: Face Milling Cutter

2.3 Surface Roughness in Milling Process

Surface roughness is defined by various characteristics of the surface profile such as centre-line average ***R,,*** peak-to-valley height ***R,*** and average roughness depth , but these have limitations. The randomness of the profile is not measured by any of these parameters. The randomness of the surface profile causes the roughness value to vary under the given cutting conditions and is caused by the random nature of the mechanism of formation of the built-up edge, side flow and tool wear. The randomness of the profile may be assessed from the auto-correlation function of the profile. There are various simple surface roughness amplitude parameters used in industry, such as roughness average (Ra), root-mean-square (rms) roughness (Rq), and maximum peak-to-valley roughness (Ry or Rmax). The parameter Ra is used in this study. The average roughness (Ra) is the area between the roughness profile and its mean line, or the integral of the absolute value of the roughness profile height over the evaluation length. Therefore, the Ra is specified by the following equation:

$$\mathrm{Ra} = \frac{1}{L}\int_0^L |Y(x)|\,\mathrm{d}x,$$

where Ra is the arithmetic average deviation from the mean line, L is the sampling length, and Y is the ordinate of the profile curve.

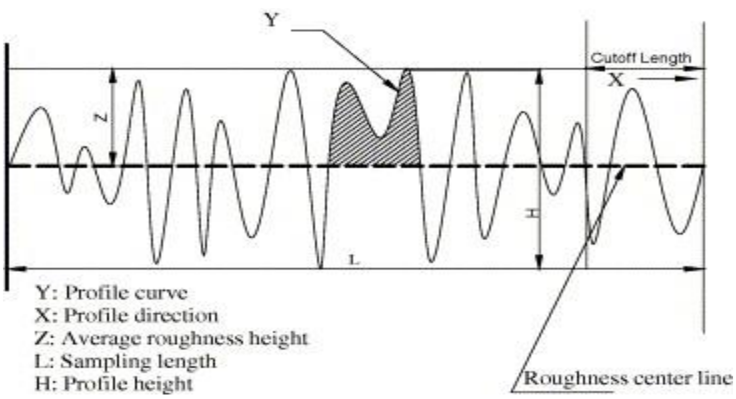

Figure 2.6: Surface Roughness Graph

2.3.1 Multiple Regression Prediction Model

The proposed multiple regression models are a three-way interaction equation:

$$Y_i = \alpha_i + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{1i} X_{2i} + \beta_5 X_{1i} X_{3i} + \beta_6 X_{2i} X_{3i} + \beta_7 X_{1i} X_{2i} X_{3i} \tag{2.1}$$

Where

Yi: surface roughness Ra (micro mm)

Xli: spindle speed (revolutions per minute)

X2i: feed rate (mm per minute)

X3i: depth of cut (mm)

In this study, the variable of the surface roughness (Ra) and the predictor variables are spindle speed, feed rate, and depth of cut. Because these variables are controllable machining parameters, they can be used to predict the surface roughness in milling which will then improve product quality.

2.4 Response Surface Method (RSM)

2.4.1 Introduction to Response Surface Method (RSM)

Response Surface Methodology (RSM) is a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes. The most extensive applications of RSM are in the particular situations where several input variables potentially influence some performance measure or quality characteristic of the process. Thus performance measure or quality characteristic is called the response. The input variables are sometimes called independent variables, and they are subject to the control of the scientist or engineer. The field of response surface methodology consists of the experimental strategy for exploring the space of the process or independent variables, empirical statistical modeling to develop an appropriate approximating relationship between the yield and the process variables, and optimization methods for finding the values of the process variables that produce desirable values of the response. In this report we will concentrate on the second strategy statistical modeling to develop an appropriate approximating model between the response *y* and independent variable $\xi 1,\xi 2 ,...,\xi\ k$.

In general, the relationship is

$$y = f(\xi 1 ,\xi 2 ,...,\xi k) + \varepsilon ; \quad (2.2)$$

where the form of the true response function *f* is unknown and perhaps very complicated,

and ε is a term that represents other sources of variability not accounted for in *f*. Usually ε

includes effects such as measurement error on the response, background noise, the effect of other variables, and so on. Usually ε is treated as a statistical error, often assuming it to have a normal distribution with mean zero and variance σ^2 . Then

$$E(y) = \eta = E [f (\xi 1 ,\xi 2 ,...,\xi k)] + E (\varepsilon) = f (\xi 1 ,\xi 2 ,...,\xi k); \quad (2.3)$$

The variables $\xi 1,\xi 2 ,...,\xi k$ in Equation (1.2) are usually called the natural variables, because they are expressed in the natural units of measurement, such as degrees Celsius, pounds per square inch, etc. In much RSM work it is convenient to transform the natural variables to coded variables $k\ x , x ,..., x\ 1\ 2$, which are usually defined to be dimensionless with mean zero and the same standard deviation. In terms of the coded variables, the response function (1.2) will be written as

$$\eta = f (x1 , x2 ,..., x k); \quad (2.4)$$

Because the form of the true response function *f* is unknown, we must approximate it. In fact, successful use of RSM is critically dependent upon the experimenter's ability to develop a suitable approximation for *f*. Usually, a low-order polynomial in some relatively small region of the independent variable space is appropriate. In many cases, either a first-order or a second order model is used.[Kumaran K,1995]

The first-order model is likely to be appropriate when the experimenter is interested in approximating the true response surface over a relatively small region of the independent variable space in a location where there is little curvature in *f*.

For the case of two independent variables, the first-order model in terms of the coded variables is

$$\eta = \beta_o + \beta_1 x_1 + \beta_2 x_2 \;; \qquad (2.5)$$

The form of the first-order model in Equation (1.4) is sometimes called a main effects model, because it includes only the main effects of the two variables x_1 and x_2. If there is an interaction between these variables, it can be added to the model easily as follows:

$$\eta = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 \;; \qquad (2.6)$$

This is the first-order model with interaction. Adding the interaction term introduces
curvature into the response function. Often the curvature in the true response surface is strong enough that the first-order model (even with the interaction term included) is inadequate. A second-order model will likely be required in these situations. This model would likely be useful as an approximation to the true response surface in a relatively small region. The second-order model is widely used in response surface methodology for several reasons:

1. The second-order model is very flexible. It can take on a wide variety of functional forms, so it will often work well as an approximation to the true response surface.
2. It is easy to estimate the parameters (the β's) in the second-order model. The method of
least squares can be used for this purpose.
3. There is considerable practical experience indicating that second-order models work well in solving real response surface problems.[Kumaran K, 1995]

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The study in this reseacrh is to optimize surface roughness, Ra value by using response surface method (RSM) and neural network (NN). This chapter consist of flow chart diagram, experiment setup, design of experiment (DOE) and artificial intelligent are discussed.